TITLE: "THE SCALE-UP OF LARGE PRESSURIZED FLUIDIZED BEDS FOR ADVANCED COAL-FIRED POWER PROCESSES"

PI's: Leon GLICKSMAN and Michel LOUGE
glicks@mit.edu and louge@cornell.edu

STUDENTS AND THE DEGREE FOR WHICH THEY ARE/WERE REGISTERED:

Vincent Bricout (Ph.D. candidate, Cornell)
Elizabeth Griffith (Ph.D candidate, Cornell)
Mathew Hyre (Ph.D., MIT)
Richard Tan (S.M., MIT)
Hesham Younis (Ph.D. candidate, MIT)

INSTITUTION/ORGANIZATION: Massachusetts Institute of Technology
Department of Mechanical Engineering,
77 Massachusetts Avenue
Cambridge, MA 02139

Tel (617) 253 2233

Cornell University
Sibley School of Mechanical Engineering
Upson Hall
Ithaca, NY 14853

Tel: (607) 255-4193

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I. ABSTRACT

OBJECTIVE:

Pressurized fluidization is a promising new technology for the clean and efficient combustion of coal. Its principle is to operate a coal combustor at a high inlet gas velocity to increase the inflow of reactants, and at an elevated pressure to raise the overall efficiency of the process. Unfortunately, commercialization of large pressurized fluidized beds is inhibited by uncertainties in scaling up units from the current pilot plant levels.

In this context, our objective is to conduct a study of the fluid dynamics and solid capture of a large pressurized coal-fired unit. The idea is employ dimensional similitude to simulate in a cold laboratory model the flow in a Pressurized Circulating Fluid Bed "Pyrolyzer", which is part of a High Performance Power System (HIPPS) developed by

Foster Wheeler Development Corporation (FWDC) under the DOE's Combustion 2000 program.

WORK DONE AND CONCLUSIONS:

At MIT, the mixing and segregation behavior of dissimilar solid particles of different densities and Particle Size Distributions (PSD) in a Pressurized Circulating Fluidized Bed (PCFB) riser is investigated experimentally. A commercial pyrolyzer which consists of limestone and char can be properly designed to maximize the reaction rate if the mixing and segregation processes are clearly understood.

A combined-cycle High Performance Power System (HIPPS) capable of overall cycle efficiencies approaching 50% has been proposed and designed by Foster Wheeler Development Corporation. A pyrolyzer in the first stage of the HIPPS process converts coal feed into fuel gas and char at an elevated pressure of 1.65 MPa (240 psia) and elevated temperature of 927 °C (1700 °F). By utilizing a simplified set of scaling parameters, a 4/7th lab-scale cold model (5.73 m high and 10.2 cm in riser diameter) of the pyrolyzer operating at ambient temperature and pressure was constructed and tested. The scaling parameters matched include solid to gas density ratio, Froude number, length to diameter ratio, dimensionless superficial gas velocity and solid recycle rate, particle sphericity and PSD.

The behavior of dissimilar solids in such a pyrolyzer were simulated experimentally with varying solid recirculation rates and a superficial gas velocity of 2 m/s. Volumetric solid fraction along the riser was measured in each case. Several sampling devices located axially along the riser enabled the collection of solid bed particles at various levels. These samples were analyzed for both the PSD and material concentrations which are essential in providing a more in-depth understanding of the mixing and segregation processes.

The results indicate that particles are well mixed along the core region of the riser due to the high superficial gas velocity. The effect of an abrupt riser exit geometry is also analyzed and is believed to be responsible for a stronger presence of heavier particles within the riser. Experiments are under way to perform a similar analysis for the wall region of the bed.

At Cornell, we have carried out a series of experiments simulating conditions in a pressurized circulating bed power plant. The objective of these experiments was to validate the reduced scaling analogy proposed by our MIT partners. We have also gathered data on the ability of our primary cyclone to capture solids escaping from the top of the riser.

We found that the reduced scaling laws correctly capture the behavior of pressurized circulating fluid beds in the upper region of the riser. For that region, we have proposed a simple model predicting variations of the pressure gradient. This analysis showed that, for a wide range of experiments, two parameters capture the dependence of the pressure gradients upon the ratio of the mean gas and solid mass flow rates. The first is the ratio of the mean particle slip and superficial gas velocities. The second represents spatial correlations between the radial profiles of interstitial gas velocity and voidage. Variations of the first with dimensionless parameters indicated that our “atmospheric” and “pressurized” experiments conformed to distinct viscous and inertial regimes.

Results from the model also suggested that solid clusters play an important role in setting the pressure gradient. In this context, we have analyzed the velocity of descending clusters at the wall and proposed a simple correlation to describe it.

SIGNIFICANCE TO FOSSIL ENERGY PROGRAM:

These activities are conducted with Foster Wheeler Development Corporation (FWDC), which is developing a High Performance Power System (HIPPS) under the DOE's Combustion 2000 program.

II. ARTICLES AND PRESENTATIONS

IFPRI meeting, Osaka: “Circulating Fluidized Bed Research at Cornell,” June 9, 1997.

Louge M.Y., Bricout V. and Martin-Letellier S.: “On the dynamics of pressurized and atmospheric circulating fluidized bed risers,” *Chem. Eng. Sci.*, December 1997, under review.

Elizabeth Griffith and M. Louge: “The Scaling of Cluster Velocity at the Wall of Circulating Fluidized Bed Risers,” *Chem. Eng. Sci.* **53** (1998).

Glicksman, L.R., P.A. Farrell and M.R. Hyre, “Simplification of the Scaling Laws for Fluidized Bed Hydrodynamics,” to be presented at the Third International Conference on Multiphase Flow, Lyon, France, 1998.

Younis, H.F., R.H. Tan and L.R. Glicksman, “Experimental Simulation of the Hydrodynamics of Dissimilar Solids in a Pressurized Circulating Fluidized Bed,” to be presented at the PTF Topical Conference at the 1998 AIChe Annual Meeting, Miami Beach, Florida, USA, 1998.

Younis, H.F. and L.R. Glicksman, “Measurement and Prediction of the Hydrodynamics of Binary Mixtures in a Pressurized Circulating Fluidized Bed,” to be presented at the 6th International Conference on Circulating Fluidized Beds, Wurzburg, Germany, 1999.